Optical SOLO Autonomous Profiler Development and Operational Deployment in the Japan-East Sea

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LONG-TERM GOALS

To develop an inexpensive, autonomous optical profiling system for spectral diffuse attenuation coefficients (K-SOLO) that is independent of calibration errors and to develop models for estimating inherent and apparent optical properties of the ocean from K determined for 3 wavelengths.

OBJECTIVES

We are developing a 3-channel irradiance sensor with large dynamic range that will be integrated to the autonomous profiling SOLO (Sounding Oceanographic Lagrangian Observer) platform. Using models based on our large *in situ* optical data set, we will develop methods to derive spectral K, reflectance, absorption, scattering and backscattering from the estimates of K at 3 wavelengths that the system will measure.

APPROACH

The inability of surface vessels to sustain observations at a particular location for more than a few weeks and their high operating cost requires an alternative approach to obtaining time series of ocean optical parameters at global scales. Fixed near surface moorings (e.g. BioWATT, MLML) provide high temporal resolution but their high costs will preclude large space-scale observations. Optical satellites can provide significant temporal and spatial coverage, but are restricted to the surface, and are useless in cloudy conditions. The system we are developing will complement the time-space observation domain of other traditional systems.

K-SOLO integrates existing and proven instrumentation into an autonomous profiling spectral diffuse attenuation meter system that communicates via ARGOS satellite. We will integrate a Biospherical instruments PER300 3-wavelength (412, 490, 555 nm) irradiance sensor to a SOLO profiler configured with the ideal wavelengths determined from this analysis. Using our large optical data set, we are developing models to estimate inherent optical properties (absorption, scattering, backscattering), chlorophyll and bulk pigment biomass from spectral K.

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Two decades of work combining field measurements of inherent and apparent optical properties of the ocean with bio-optical modeling have led to an advanced understanding of the relationships between optics and organic mass (carbon, pigments) and the physical stratification of the ocean. We will analyze our large (>700 bio-optical profiles) data set obtained from diverse oceanic regions on various cruises in the past 5 years (CalCOFI, JGOFS Southern Ocean, INDOEX, ONR JES) to develop the models. The data set includes direct measurement K, R, Rrs, a, c, bb, chlorophyll and other pigments so that we will be able to refine models relating K to variables of interest, including hyperspectral reflectance and inherent optical properties.

After integration and testing, we will deploy our prototype system in the Japan/East Sea to characterize physical stratification and the spring bloom. Data obtained from optical surveys in 1999 and 2000 in the JES will allow us to refine our model parameterizations for regional applications.

WORK COMPLETED

The optical raidometer has been designed and built. Mechanical, electronic and data interface between the radiometer and the SOLO is in progress and will be complete before the end of 1999. Data relay algorithms for the spectral irradiance data have been developed to allow maximum information to be relayed via the low bandwidth and relatively unreliable ARGOS satellite data communication system.

Consideration of Bio-fouling

We recognize that bio-fouling must be considered for optical systems. Rather than invest greater resources in cleaning or anti-fouling mechanisms, we will simply estimate K, the diffuse attenuation coefficient, rather than absolute irradiance. The relevant relationships for our application is given by the following equation:

$$K = (-\ln [Ed(z)/Ed(z+n)])/n \qquad (1)$$

where K has units of inverse meters, Ed is the measured downwelling irradiance at any depth z and n is the depth range (meters) over which K is estimated. By taking the ratio of irradiances measured close in time (seconds) during profiles of the SOLO, any bio-fouling can safely be assumed to be constant for such a time domain over the narrow spectral bands of the instrument. Therefore, accurate estimates of K will be possible even if large errors in Ed are caused by bio-fouling. The unit's free-fall ascent and descent properties will make it an ideal system to acquire unperturbed vertical values of K over large time and space scales in the ocean.

RESULTS

We have evaluated our large CalCOFI data set to demonstrate that 3 spectral bands of K improve the estimation of spectral K as well as chlorophyll concentrations, compared to a single estimate of K(490). It has been demonstrated previously (Austin and Petzold, 1981; Mitchell and Kahru, 1998) that $K(\lambda)$ is highly correlated to K(490) in single linear regression between K(490) and K at any other wavelength for near-UV and visible wavelengths. Figure 1 is the spectral plot of the squared correlation coefficients (R^2) for the single linear regression correlation, and also for a multiple linear correlation determination using K(412), K(490) and K(555) to estimate the spectral K. One notes that the R^2 for the single linear correlation using K(490) drops precipitously below 400 nm and above 550 nm. Using a 3-wavelength multiple correlation method, correlation coefficients are higher throughout the spectrum, and significant deterioration occurs only below 390 nm and above 570 nm. Figures 2A and 2B are the observed versus predicted K(380) using the single linear regression coefficients with K(490), and for the 3-wavelength multiple regression, respectively. This near-UV region is a good test of the improved ability of the multi-wavelength regression method since it is in the region where the single K(490) approach starts to have severe degradation in describing the variance. It is evident that the power of prediction is vastly improved with the multiple regression approach, and also one notes a curvature in the single regression plot (Figure 2A) that probably is caused by changes in the types of scattering and absorbing material found in low and high biomass waters. These data imply an important benefit by using multiple wavelengths if one wishes to retrieve robust estimates of hyperspectral K with confidence from simple and inexpensive instruments. Similar advantages for chlorophyll retrieval were found (data not shown). Our 3-wavelength K estimates from K-SOLO will allow us to obtain low cost autonomous estimates of the hyperspectral diffuse attenuation coefficient of the ocean with relatively high spectral fidelity and high accuracy since bio-fouling is not of concern.

Preliminary design and performance specifications have been met for the development of K-SOLO. Integration is proceeding for final testing in early 2000 and deployment in March of 2000. The design criteria, optical model development and integration milestones will be presented at the annual Ocean Sciences meeting (Chen et al., 2000)

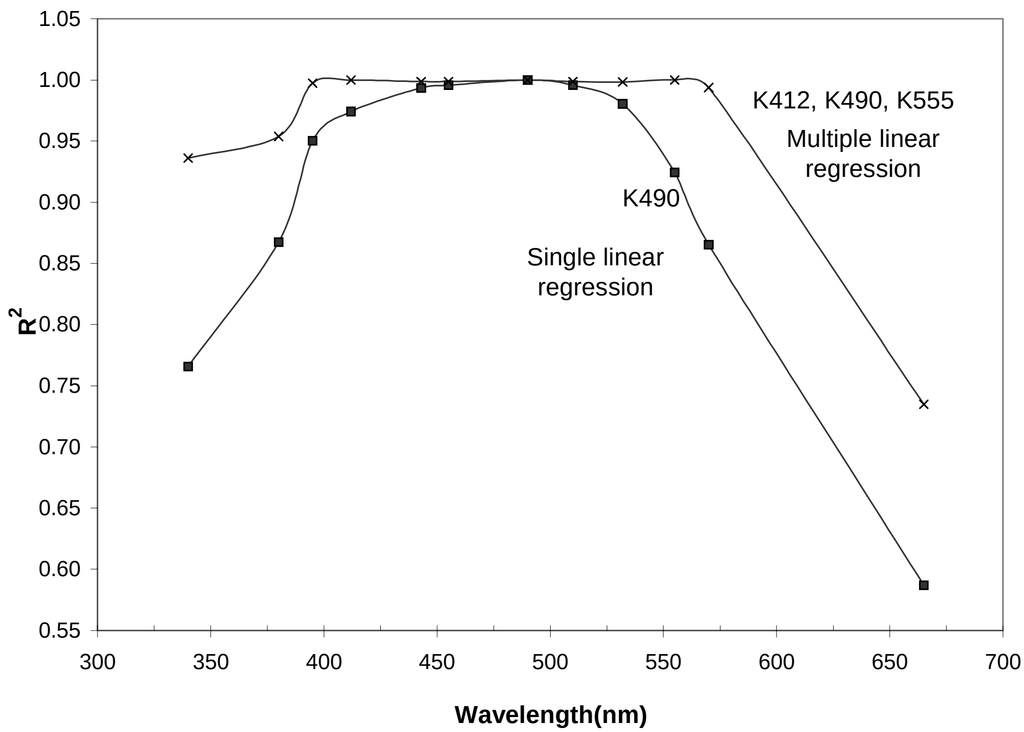
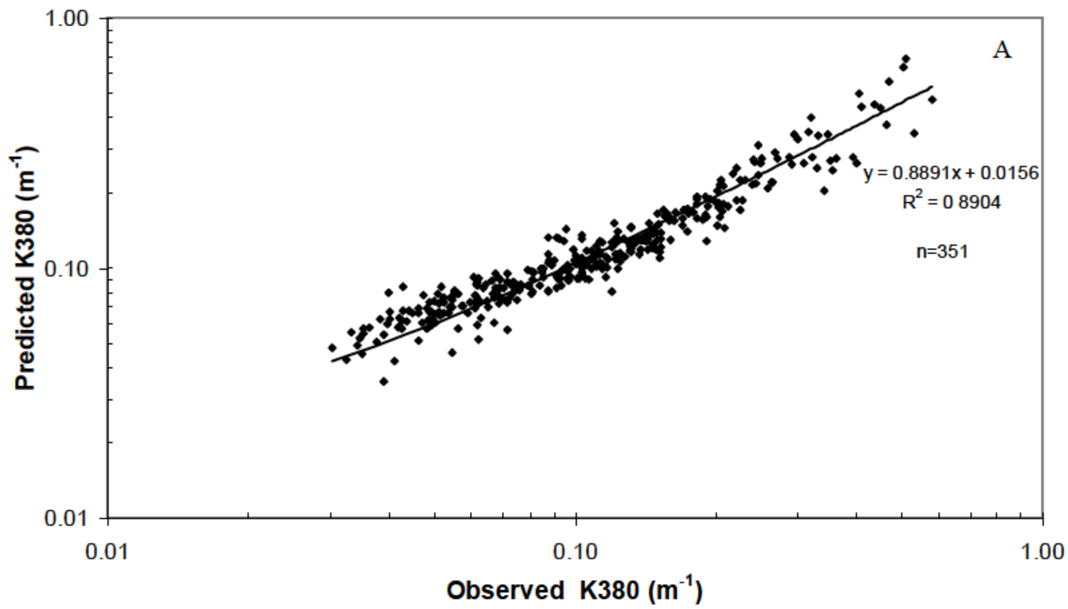


Figure 1. Spectral distribution of the squared correlation coefficient (R^2) for the single linear correlations between K(λ) and K(490), and for a multiple linear regression fit predicting K(λ) from K(412), K(490), and K(555).



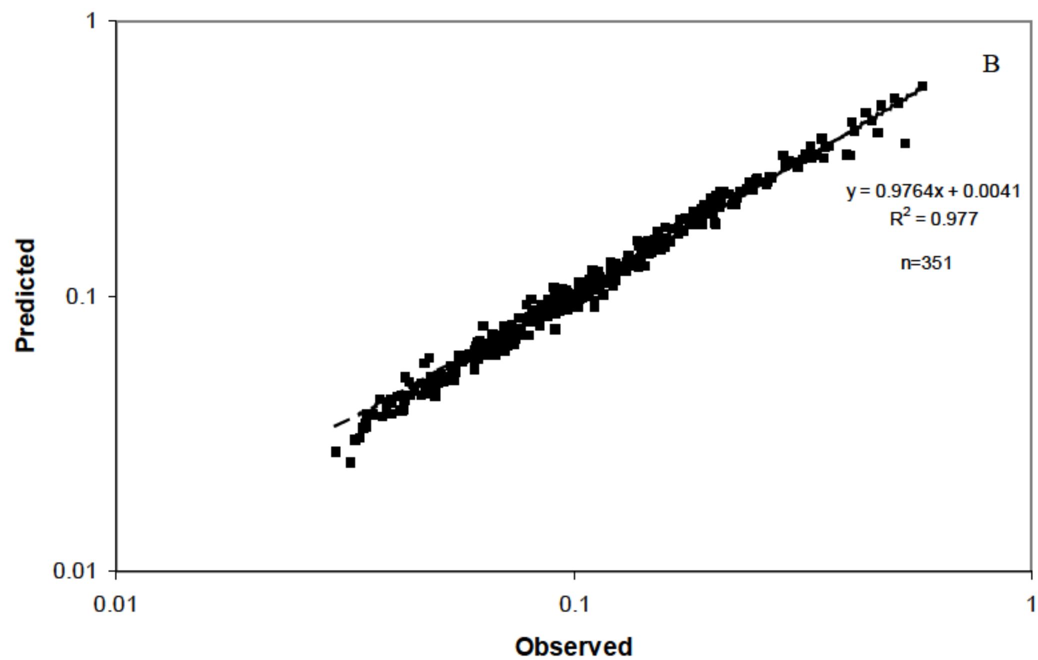


Figure 2. A. Predicted K(380) plotted against observed K(380) for the single linear correlation fit of K(λ) versus K(490). B. As in Figure 3A. but for the three-channel multiple linear regression using multiple K(412), K(490), and K(555). A very significant improvement in the fit is noted for the 3 wavelength approach compared to the single wavelength K(490) approach.

IMPACT/APPLICATIONS

The system we are developing will have an important impact by providing low cost capability for autonomous estimates of optical properties in the ocean. The autonomous capability will allow the system to provide data for extended periods of time in regions of interest without the need for ship support. The channel at 490 nm will provide a direct measurement of K490 that is independent of ship shadow effects. After successful testing and the demonstration deployment, we anticipate that the optical radiometer will be a standard option for SOLO configuration in the future. The systems will prove valuable in diverse applications ranging from autonomous optical observation in regions with difficult access to global validation of ocean color remote sensing products. In particular, K-SOLO will be the most accurate and cost-effective validation system for K(490) – one of the standard products of all existing or planned ocean color satellite missions.

TRANSITIONS

Development of PER 300 radiometer with 3-channel Ed and 2000 m depth range. Development of models to derive hyperspectral K, reflectance, absorption and backscattering from estimates of K at only 3-wavelengths.

RELATED PROJECTS

The development of K-SOLO depends on the separate development program for SOLO as a physical oceanographic autonomous profiler. Also, the Scripps Instrument Development Group who pioneered ALACE and SOLO autonomous profilers have recently been awarded funds under the National Ocean Partnership Program to upgrade SOLO. Thus, the optical integration we are accomplishing now will benefit the community by providing an option for future configurations of the more advanced SOLO that will be available by 2000.

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PUBLICATIONS

Chen, X. and B.G. Mitchell (2000) Design Criteria And Preliminary Applications Algorithms For An Autonomous Profiling Physical-Optical System (K-SOLO). AGU, San Antonio, TX. Jan. 24, 2000

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